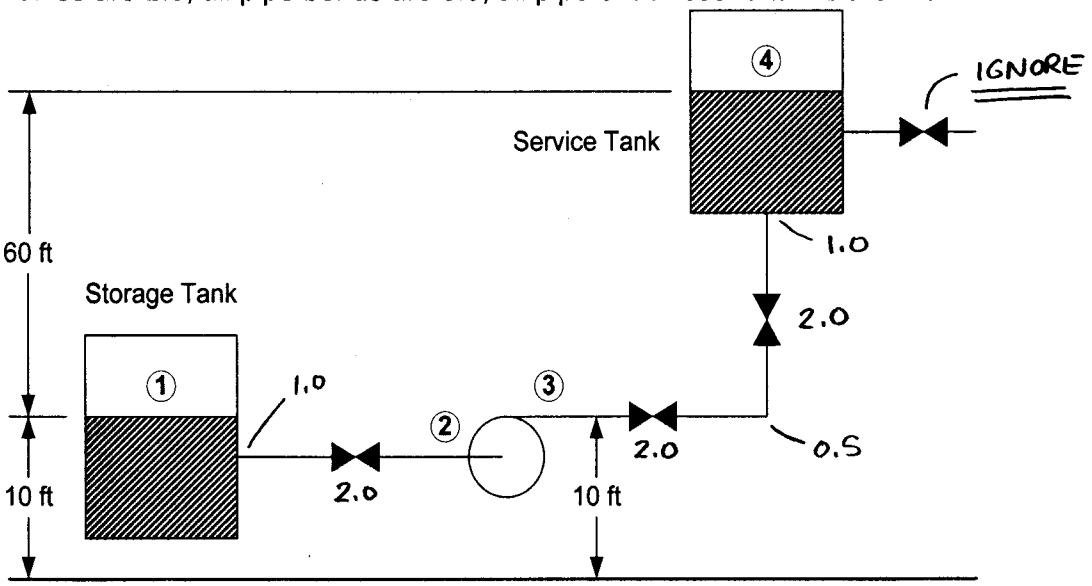
INCOMPRESSIBLE FLUID FLOW EXAMPLE

Fuel (density of 49 lb_m/ft^3) is transferred from an underground storage tank to an above ground service tank. A pump rated at 2 hp is used to provide a fuel flow rate of 28 gpm. The length of piping from 1 → 2 is 80 ft, and the length of piping from 3 → 4 is 320 ft. The pipe diameter is 2.4 inches and friction factor is 0.004. The pump output pressure is 35 psia and the storage tank pressure is 1 psig. Assume atmospheric pressure is 15 psia. K factors: all valves are 2.0, all pipe bends are 0.5, all pipe entrances to tanks are 1.0.

$\rho = 49 \frac{lbm}{ft^3}$

$\gamma = \rho\left(\frac{g}{g_c}\right)$

$\gamma = 49 \frac{lbf}{ft^3}$



Find: (a) Fuel velocity in piping [ft/s]:
(b) Pump efficiency [%]:
(c) Pressure in the service tank, p_4 [psia]:

Ⓐ $\dot{\forall} = A\vec{V}$

$28 \frac{GAL}{MIN}\left(\frac{1\ FT^3}{7.48\ GAL}\right)\left(\frac{1\ MIN}{60\ S}\right) = \frac{\pi}{4}\left(\frac{2.4}{12}\ FT\right)^2 \vec{V}$

$\boxed{\vec{V} = 2.0 \frac{FT}{S}}$

FOR NEXT STEP

$\dot{m} = \rho\dot{\forall}$

$= 49 \frac{lbm}{ft^3}\left(28 \frac{GAL}{MIN}\right)\left(\frac{1\ FT^3}{7.48 GAL}\right)\left(\frac{1\ MIN}{60\ S}\right)$

$\dot{m} = 3.06 \frac{lbm}{S}$

Ⓑ $w_p\left(\frac{g_c}{g}\right) = (z_3 - z_1)^{0} + \frac{1}{\gamma}(p_3 - p_1) + \frac{1}{2g}(\vec{V}_3^2 - \vec{V}_1^2)^{0} + H_{L13}$

$= \frac{1}{49 \frac{lbf}{ft^3}}(35-16)\frac{lbf}{in^2}\left(\frac{144\ in^2}{ft^2}\right) + \frac{1}{64.4 \frac{ft}{s^2}}\left(2.0 \frac{ft}{s}\right)^2 + \left[.004\left(\frac{80\ ft}{2.4/12\ ft}\right) + 3\right]\frac{(2.0 \frac{ft}{s})^2}{64.4 \frac{ft}{s^2}}$

$= 55.8\ FT + .06\ FT + .29\ FT$

$w_p = 56.2 \frac{FT\ LBF}{LBm}$ ⟸ ISENTROPIC (IDEAL) w_p

$whp = \dot{m} \times w_p(ISEN) = 3.06 \frac{lbm}{s}\left(56.2 \frac{FT\ LBF}{LBm}\right)\left(\frac{1\ HP}{550 \frac{FT\ LBF}{S}}\right) = .313\ HP$

$bhp = 2\ HP$ (NOTE: "RATED AT" MEANS bhp)

$\eta_p = \frac{whp}{bhp} = \frac{.313\ HP}{2\ HP} \Rightarrow \boxed{\eta_p = 15.7\%}$

(c) TWO WAYS TO FIND p_4: 1) BERNOULLI FROM $1 \to 4$
2) BERNOULLI FROM $3 \to 4$

USING $1 \to 4$

$$w_p\left(\frac{g_c}{g}\right) = (z_4 - z_1) + \frac{1}{2g}\left(\cancel{\vec{V}_4^{\,2}}^{\,0} - \cancel{\vec{V}_1^{\,2}}^{\,0}\right) + \frac{1}{\gamma}(p_4 - p_1) + H_{L14}$$

$$56.2\,FT = (70-10)FT + \frac{1}{49\,\frac{LBF}{FT^3}}(p_4 - 16)\frac{LBF}{IN^2}\left(\frac{144\,IN^2}{FT^2}\right) + \left[.004\left(\frac{400\,FT}{2.4/12\,FT}\right) + 8.5\right]\frac{(2.0\,\frac{FT}{S})^2}{64.4\,\frac{FT}{S^2}}$$

$$56.2\,FT = 60\,FT + \frac{1}{49\,\frac{LBF}{FT^3}}(p_4 - 16)\frac{LBF}{IN^2}\left(\frac{144\,IN^2}{FT^2}\right) + 1.0\,FT$$

$$\boxed{p_4 = 14.4\ PSIA}$$

USING $3 \to 4$

$$\cancel{w_p}^{\,0}\left(\frac{g_c}{g}\right) = (z_4 - z_3) + \frac{1}{2g}\left(\cancel{\vec{V}_4^{\,2}}^{\,0} - \vec{V}_3^{\,2}\right) + \frac{1}{\gamma}(p_4 - p_3) + H_{L34}$$

$$0 = (70-10)FT + \frac{1}{64.4\,\frac{FT}{S^2}}\left(0 - (2.0\,\tfrac{FT}{S})^2\right) + \frac{1}{49\,\frac{LBF}{FT^3}}(p_4 - 35)\frac{LBF}{IN^2}\left(\frac{144\,IN^2}{FT^2}\right)$$

$$+ \left[.004\left(\frac{320\,FT}{(2.4/12)FT}\right) + 5.5\right]\frac{(2.0\,\frac{FT}{S})^2}{64.4\,\frac{FT}{S^2}}$$

$$0 = 60\,FT + (-.06\,FT) + \frac{1}{49\,\frac{LBF}{FT^3}}(p_4 - 35)\frac{LBF}{IN^2}\left(\frac{144\,IN^2}{FT^2}\right) + 0.74\,FT$$

$$\boxed{p_4 = 14.4\ PSIA}$$

NOTE: BERNOULLI'S EQN CAN BE APPLIED BTWN ANY 2 POINTS.
USE THE POINTS FOR WHICH YOU HAVE THE MOST INFO
(ie YOU ARE LEFT WITH ONE UNKNOWN VARIABLE —
HOPEFULLY IT IS THE VARIABLE YOU NEED TO FIND!)